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Patent claims

1. A regulatable spring-and-damper system in a vehicle, with a spring element (5) and a damping element (9) mounted in parallel, one of the elements being configured in an adjustable manner, characterized in that, to realize a semi-active system (4), the spring element (5) is passive and the damping element (9) is configured with a damping characteristic that can be regulated in a variable manner and the semi-active system (4) can be described according to the force profile (F_S)

$$F_S = -c \cdot z - d_u \cdot \dot{z}$$

where

- c denotes a spring constant of the passive spring element (5)
- d_u denotes a damping value that can be regulated in a variable manner
- z denotes a state variable of the system
- $\dot{z}$ denotes the derivative with respect to time of the state variable,

and in that the damping element (9) is regulated by the damping value (d_u) following at least approximately the relationship

$$d_u = \frac{-c \cdot z + f(z, \dot{z}, u, \dot{u})}{\dot{z}}$$

where

- u denotes a manipulated variable
- $\dot{u}$ denotes the derivative with respect to time of the manipulated variable
- f denotes a known function,

the function (f) is known from an actively regulatable reference system (1) with an adjustable final control element (6) and the force profile

(F_R) of the reference system (1) can be described by the relationship

$$F_R = -f(z,\dot{z},u,\dot{u})$$

the manipulated variable (u) or the derivative with respect to time ($\dot{u}$) of the manipulated variable of the adjustable final control element (6) being determinable in a closed-loop and open-loop control unit according to a stored mathematical relationship.

2. The spring-and-damper system as claimed in claim 1, characterized in that the damping value (d_u) is regulated according to the approximation function

$$d_u \approx \frac{\dot{z}}{\text{limit}\left[\dot{z}^2\right]_v^\infty}\left\{-c\cdot z + f(z,\dot{z},u,\dot{u})\ \right\}$$

where $\text{limit}\left[\dot{z}^2\right]_v^\infty$ denotes the lower, permissible limit (v) and the upper limit (∞) for the square of the rate of the state variable (z).

3. The spring-and-damper system as claimed in claim 1 or 2, characterized in that the spring stiffness (c) of the passive spring element (5) in the case of a gas spring follows the relationship

$$c = \left(\frac{p_{FS}}{p_0}\right)^{\frac{k+1}{k}} c_0$$

in which

p_0 denotes a reference pressure

c_0 denotes the spring stiffness at the reference pressure

p_{FS} denotes the pressure in the gas accumulator of the spring element (5)

k denotes the isentropic exponent of the gas in the gas accumulator.

4. The spring-and-damper system as claimed in one of claims 1 to 3, characterized in that, in the case of an actively regulatable reference system (1), which comprises a passive spring element (5), a final control element (6) mounted in series with the passive spring element (5) and a passive damping element (7) mounted in parallel with the passive spring element (5) and the final control element (6) and can be described by the function

$$f = d \cdot \dot{z} + c(z - u)$$

the damping value (d_u) of the regulatable damping element (9) is regulated according to the relationship

$$d_u = \frac{-c \cdot z + f}{\dot{z}} = d - \frac{c \cdot u}{\dot{z}}$$

5. The spring-and-damper system as claimed in one of claims 1 to 4, characterized in that, in the case of an actively regulatable reference system (1), which comprises a passive spring element (5), a passive damping element (7) mounted in parallel with the passive spring element (5) and a final control element (6) mounted in series with both elements (5, 7) and can be described by the function

$$f = d(\dot{z} - \dot{u}) + c(z - u)$$

the damping value (d_u) of the regulatable damping element (9) is regulated according to the relationship

$$d_u = \frac{-c \cdot z + f}{\dot{z}} = d - \frac{d \cdot \dot{u} + c \cdot u}{\dot{z}}$$

6. The spring-and-damper system as claimed in claim 5, characterized in that, to realize a semi-active, hydropneumatic spring strut as an adjustable damping element (9), a regulatable throttle is

provided, arranged in a line (11) between a displacer (10) and the hydraulic side of a hydropneumatic spring accumulator as the spring element (5), the damping value (d_u) being regulatable by adjustment of the throttle.

7. The spring-and-damper system as claimed in claim 6, characterized in that the first derivative ($\dot{u}$) of the manipulated variable is proportional to a volumetric flow of oil (Q_{AHP}) through the regulatable final control element (6) of the reference system (1):

$$\dot{u} = \frac{Q_{AHP}}{A_{HK}} \quad ,$$

where
A_{HK} denotes the surface area of the main chamber of the displacer (10).

8. The spring-and-damper system as claimed in one of claims 1 to 7, characterized in that the manipulated variable (u) is high-pass-filtered in the closed-loop and open-loop control unit according to the relationship

$$u_{HP} = \frac{T_{HP} \cdot \dot{u}}{T_{HP} \cdot \dot{u} + u}$$

where
T_{HP} denotes a gain factor which is determined according to the relationship

$$T_{HP} = \frac{1}{2 \cdot \pi \cdot f_{HP}}$$

in which f_{HP} denotes the cutoff frequency of the high-pass filter.

9. The regulatable spring-and-damper system in a vehicle, with a spring element (5) and a damping

element (9) mounted in parallel, one of the elements being configured in an adjustable manner, characterized in that, to realize a semi-active system (4), the spring element (5) is passive and the damping element (9) is configured with a damping characteristic that can be regulated in a variable manner and the semi-active system (4) can be described according to a force profile (F_S) which can be represented as a function of a variable describing the spring constant (c) of the passive spring element (5) and/or of a variable describing a damping value (d_u) that can be regulated in a variable manner and/or of a variable describing a state variable (z) of the system and/or of a variable describing the derivative with respect to time ($\dot{z}$) of the state variable and in that the damping element (9) is regulated by the damping value (d_u) following at least approximately a relationship which can be represented as a function of the variable describing the spring constant (c) of the passive spring element (5) and/or of a manipulated variable (u)and/or of a variable describing the derivative with respect to time ($\dot{u}$) of the manipulated variable and/or of the variable describing the state variable (z) of the system and/or of the variable describing the derivative with respect to time ($\dot{z}$) of the state variable, this relationship being based on a function (f) which is known from an actively regulatable reference system (1) with an adjustable final control element (6) and the force profile (F_R) of the reference system (1) being able to be described according to a relationship which can be represented as a function of the manipulated variable (u) and/or of the variable describing the derivative with respect to time ($\dot{u}$) of the manipulated variable and/or of the variable describing the state variable (z) of the system

and/or of the variable describing the derivative with respect to time ($\dot{z}$) of the state variable, with the manipulated variable (u) and/or the variable of the adjustable final control element (6) describing the derivative with respect to time ($\dot{u}$) of the manipulated variable being determinable in a closed-loop and open-loop control unit according to a stored mathematical relationship.